IN THE SPECIFICATION

Please replace paragraphs 20, 37, 38, 40, 41, 43, 52, 59, 76, 78, 82, 84, 86, 88, 93, 122, 133, 137, and 138 with the following paragraphs:

[0020] Figure ~~10~~ 11 is an exploded perspective view of a fourth embodiment of a fuse.

[0037] As appreciated by those in the art, performance of the fusible link (e.g. short circuit ~~performance~~ and interrupting ~~voltage~~ capability) is dependant upon and primarily determined by the melting temperature of the materials used and the geometry of the fusible link, and through variation of each a virtually unlimited number of fusible links having different performance characteristics may be obtained. In addition, more than one fusible link may extend in parallel to further vary fuse performance. In such an embodiment, multiple fusible links may extend in parallel between contact pads in a single fuse element layer or multiple fuse element layers may be employed including fusible links extending parallel to one another in a vertically stacked configuration.

[0038] To select materials to produce a fuse element layer 20 having a desired fuse element rating, or to determine a fuse element rating fabricated from selected materials, it has been determined that fusing performance is primarily dependant upon three parameters, including fuse element geometry, thermal conductivity of the materials surrounding the fuse element, and a melting temperature of the fusing metal. It has been determined that each of these parameters ~~are directly proportionate to arcing time when the fuse operates, and in combination each of these parameters~~ determine the time versus current characteristics of the fuse. Thus, through careful selection of materials for the fuse element layer, materials surrounding the fuse element layer, and geometry of the fuse element layer, acceptable low resistance fuses may be produced.

[0040] Referring to Figure 6, a fuse element layer in the general shape of a capital I is formed on an insulating layer. Fusing characteristics of the fuse element layer are governed by the electrical conductivity (ρ) of the metal used to form fuse element layer, dimensional aspects of the fuse element layer (i.e., length and width of fuse element) and the thickness of the fuse element layer. In an illustrative embodiment, the fuse element layer 20 is formed from a 3 micron thick copper foil, which is known to have a sheet resistance (measured for a 1 micron thickness) of $1/\rho$*cm or about 0.016779Ω/□ where □ is a dimensional ratio of the fuse element portion under consideration expressed in "squares."

[0041] For example, considering the fuse element shown in Figure 6, the fuse element includes three distinct segments identifiable with dimensions l_1 and w_1 corresponding to the first segment, l_2 and w_2 corresponding to the second segment and l_3 and w_3 corresponding to the third segment. By summing the squares in the segments the ~~resistivity~~ resistance of the fuse element layer may be approximately determined in a rather direct manner. Thus, for the fuse element shown in Figure 6:

$$Number of\ squares = \left({}^{l_1}\!/\!_{w_1} + {}^{l_2}\!/\!_{w_2} + {}^{l_3}\!/\!_{w_3} \right) \qquad (1)$$

$$= \left({}^{10}\!/\!_{20} + {}^{30}\!/\!_{4} + {}^{10}\!/\!_{20} \right)$$

$$= 8.5\ \square\text{'s.}$$

Now the electrical resistance (R) of the fuse element layer may be determined according to the following relationship:

Fuse Element R = (Sheet Resistivity)*(Number □'s)/T (2)

where T is a thickness of the fuse element layer. Continuing with the foregoing example and applying Equation (2), it may be seen that:

Fuse Element Resistance = (0.016779Ω/□)*(8.5 □)/3

$$= 0.0475\ \Omega.$$

Of course, a fuse element resistance of a more complicated geometry could be likewise determined in a similar fashion.

[0043] While Equation (3) may be studied in great detail to determine precise heat flow characteristics of a layered fuse construction, it is presented herein primarily to show that heat flow within the fuse is proportional to the thermal conductivity of the materials used. Thermal conductivity of some exemplary known materials are set forth in the following Table, and it may be seen that by reducing the conductivity of the insulating layers employed in the fuse around the fuse element, heat flow within the fuse may be considerably reduced. Of particular note is the significantly lower thermal conductivity of polyimide, which is employed in illustrative embodiments of the invention as insulating material above and below the fuse element layer.

[0052] Lower outer insulating layer 28 underlies lower intermediate insulating layer 24 and is solid, i.e., has no openings. The continuous solid surface of lower outer insulating layer ~~24~~ 28 therefore adequately insulates fusible link 30 ~~beneath~~ above fusible link opening 42 of lower intermediate insulating layer ~~28~~ 24.

[0059] After outer insulation layers 26, 28 (layers 1 and 5) are laminated 70 to form a five layer combination, termination openings 46, 48 (shown in Figure 2) are formed 72, according to known methods and techniques into upper outer insulating layer 26 (layer 1) such that fuse element contact pads 32, 34 (shown in Figure 2) are exposed through upper outer insulation layer 26 (layer 1) and upper intermediate insulation layer 22 (layer 2) through respective termination openings 36, 38, and 46, 48. Lower outer insulating layer 28 (layer 5) is then marked 74 with indicia pertaining to operating characteristics of fuse 10 (shown in Figures 1 and 2), such as voltage or current ratings, a fuse classification code, etc. Marking 74 may be performed according to known processes, such as, for example, laser marking, chemical etching or plasma etching. It is appreciated that other known conductive contact pads, including but not

limited to Nickel/Gold, Nickel/Tin, ~~Nickel/Tin/Lead~~ Nickel/Tin-Lead and Tin plated pads, may be employed in alternative embodiments in lieu of solder contacts 12.

[0076] Upper outer insulation layer 26 overlies upper intermediate layer 22 and includes a continuous surface 50 extending over upper outer insulating layer 26 and overlying fusible link opening 40 of upper intermediate insulating layer 22, thereby enclosing and adequately insulating fusible link 30. Notably, and as illustrated in Figure 11, upper~~-intermediate~~ outer layer 122 does not include termination openings 46, 48 (shown in Figures 2-5).

[0078] Lower outer insulating layer 124 underlies lower intermediate insulating layer 24 and is solid, i.e., has no openings. The continuous solid surface of lower outer insulating layer 124 therefore adequately insulates fusible link 30 beneath fusible link opening 42 of lower intermediate insulating ~~layer 28~~ layer 24.

[0082] Using these designations, Figure 12 is a flow chart of an exemplary method 150 of manufacturing fuse 120 (shown in Figure 11). Foil fuse element layer 20 (layer 3) is laminated 152 to lower intermediate layer 24 (layer 4) according to known lamination techniques to form a metallized construction. Foil fuse element layer 20 (layer 3) is then formed 154 into a desired shape upon lower intermediate insulating layer 24 (layer 4) using known techniques, including but not limited to use of a ferric chloride solution etching process. In an exemplary embodiment, foil fuse element layer 20 (layer 3) is formed such that the capital I shaped foil fuse element remains as described above. In alternative embodiments, die cutting operations may be employed in lieu of etching operations to form the fusible link 30 contact pads 32, 34. It is understood that a variety of shapes of fusible elements may be employed in further and/or alternative embodiments of the invention, including but not limited to those illustrated in Figures 6-10. It is further contemplated that in further and/or alternative embodiments the fuse element layer may be metallized and formed using a sputtering process, a plating process, a screen printing process, and the like as those in the art will ~~appreciated~~ appreciate.

[0084] Fusible link openings 40 (shown in Figure 11) are then formed 158 in upper intermediate insulating layer 22 (layer 2) and fusible link opening 42 (shown in Figure 11) is formed 158 in lower intermediate insulating ~~layer 28~~ layer 24. Fusible link 30 (shown in Figure 11) is exposed within fusible link openings 40, 42 of respective intermediate insulating layers 22, 24 (layers 2 and 4). In exemplary embodiments, opening 40 are formed according to known etching, punching, drilling and die cutting operations to form fusible link openings 40 and 42.

[0086] One form of lamination that may be particularly advantageous for ~~purposed~~ purposes of the present invention employs the use of no-flow polyimide prepreg materials such as those available from Arlon Materials for Electronics of Bear, Delaware. Such materials have expansion characteristics below those of acrylic adhesives which reduces probability of through-hole failures, as well as better endures thermal cycling without delaminating than other lamination bonding agents. It is appreciated, however, that bonding agent requirements may vary depending upon the characteristics of the fuse being manufactured, and therefore that lamination bonding agents that may be unsuitable for one type of fuse or fuse rating may be acceptable for another type of fuse or fuse rating.

[0088] After outer insulation ~~layers 26, 28~~ layers 122, 124 (layers 1 and 5) are laminated 160 to form a five layer combination, elongated through holes corresponding to slots 126, 128 are formed 164 through the five layer combination formed in step 160. In various embodiments, slots 126, 128 are laser machined, chemically etched, plasma etched, punched or drilled as they are formed 164. Slot termination strips 134, ~~126~~ 136 (shown in Figure 11) are then formed 166 on the metallized outer surfaces of outer insulation layers 122, 124 through an etching process, and fuse element layer 20 is etched 166 to expose fuse element layer contact pads 32, 34 (shown in Figure 11) within termination slots 126, 128. After etching 166 the layered combination to form termination strips 134, 136 and etching fuse element layer 20 to expose fuse element layer contact pads 32, 34, the termination slots 126, 128 are metallized 168 according to a plating process to complete the metallized contact terminations in slots 126, 128.

In exemplary embodiments, Nickel/Gold, Nickel/Tin, ~~Nickel/Tin/Lead and Tin~~ and Nickel/Tin-Lead may be employed in known plating processes to complete terminations in slots 126, 128. As such, fuses 120 may be fabricated that are particularly suited for surface mounting to, for example, a printed circuit board, although in other applications other connection schemes may be used in lieu of surface of mounting.

[0093] It is recognized that fuse 120 may be further modified as described above in Figures 4 and 5 by elimination of one or both of fusible link openings 40, 42 in intermediate insulation layers 22, 24. The resistance of fuse 120 may accordingly be varied for different applications and different operating temperatures of fuse 120.

[00122] In an exemplary embodiment, the heat sink 232 is a ceramic or metal element located in close proximity to the fuse element, either above or below the fuse element layer 20, although it is appreciated that other heat sink materials and relative positions of the heat sink 232 may be employed in other embodiments. In one embodiment, and as shown in Figure 17, the heat sink 232 is positioned away from the warmest portion of the fuse element layer 20 in operation. That is, the heat sink 232 is positioned away from or spaced from the center of the element layer 20 or the fusible link 30 in the illustrated embodiment in Figure 17. By spacing the heat sink 232 from the fusible link 30, the heat ~~sink 231~~ sink 232 does not interfere with opening and clearing of the circuit through the fuse element layer 20.

[00133] Ideal fusing conditions are adiabatic, where there is no gain or loss of heat during a current overload condition. In an adiabatic condition, the circuit is cleared without the exchange of heat with surrounding elements. Realistically, adiabatic conditions occur only during very fast opening events wherein there is little or no time for heat to dissipate either from the terminations of the fuse or the layers of the fuse. Consistent approximate adiabatic conditions may be realized, however, by modeling an adiabatic envelope around the fusible link, thereby enclosing the fusible link in a thermodynamic system in which ~~here~~ there is no gain or loss of heat.

[00137] Figure 20 is an exploded view of a fuse manufacture 260 formed in accordance with an exemplary aspect of the invention. Like the fuses described above, the fuse ~~manufacture~~ 260 provides a low resistance fuse of a layered construction. As the ~~manufacture~~ 260 includes common elements with the foregoing embodiments, like reference characters are indicated with like reference characters in Figure 17.

[00138] In an exemplary embodiment, the fuse ~~manufacture~~ 260 includes foil fuse element layer 20 sandwiched between upper and lower intermediate insulating layers 22, 24 which, in turn, are sandwiched between upper and lower outer insulation layers 122, 124. The fuse element layer 20, and the layers 22, 24, 122 and 124 are described above in relation to Figures 11 and 12. An additional insulation layer 214 is also provided as described above in relation to Figure 15.